Contract Number W9132T-04-C-0017

ReliOn, Inc.

Midpoint Project Report

Proton Exchange Membrane (PEM) Fuel Cell Demonstration
Of Domestically Produced PEM Fuel Cells in Military Facilities

US Army Corps of Engineers
Engineer Research and Development Center
Construction Engineering Research Laboratory
Broad Agency Announcement CERL-BAA-FY03

Gray Army Air Field Instrument Landing Systems
Ft. Lewis Army Base
Tacoma, Washington

March 15, 2005

Executive Summary

The CERL fuel cell installation at Ft. Lewis near Tacoma, Washington is one of three ReliOn demonstration sites funded under the BAA-FY03 program (CERL3). The other ReliOn demonstration sites are at Ft. Rucker, Alabama (3 units at 1 kW each and 1 unit at 2 kW) and Gabreski Air National Guard Base, Long Island, New York (1 unit at 4 kW).

The project at Ft. Lewis consists of four individual installation sites – Localizer, Glide Slope, Middle Marker beacon and Outer Marker beacon. The Localizer and Glide Slope are located on Gray Army Airfield, within the property of Ft. Lewis. The Middle Marker is located outside of Gray Army Airfield but still within Ft. Lewis and the Outer Marker is gated in an area located approximately 1 mile north of Ft. Lewis on a property known as Goddard Woods. Each site utilizes one ReliOn I-1000 (1kW) fuel cell system as a source of backup power for instrument landing system (ILS) equipment.

This project is testing the reliability of the ReliOn backup power solution for U.S. Military Air Traffic Control and Landing Systems (ATCALS). The fuel cell systems are connected to the 24V DC bus at each site. The fuel cell systems are configured to monitor the commercial AC power grid as well as the status of the existing DC backup batteries at each site. Upon loss or failure of either power source, the fuel cells will start automatically to provide up to 48 kWh of continuous run power to critical equipment at each site. In addition to providing continuous protection from a primary power failure, the installation is designed to simulate a 1-hour power failure in the AC grid each day. Data are collected concerning start-up times, power availability, shutdown capability, system efficiencies, load following, and the effects of varying environmental conditions. If the system fails to start up properly or provide required power to the load this is noted in the logs as a failure and counts against the target 90% reliability and availability of the system.

These turn-key packages incorporate ReliOn's air cooled, hydrogen-fueled PEM fuel cells operating in a grid-independent mode. Because ReliOn's fuel cells operate at a relatively low temperature, cogeneration is not a part of this installation. Fuel switching is not required as the I-1000 runs on standard industrial grade hydrogen (99.95% purity), which is readily available. Specific data analyzed consists of: start-up capabilities, availability during outages, shut-down capabilities, system efficiencies, load following, maintenance operations, and effects of environmental conditions.

Key contact personnel at the host site are as follows:

Mr. William Perez
ATC Maintenance Supervisor
Gray Army Airfield
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1.0 Descriptive Title

A demonstration of modular proton exchange membrane (PEM) fuel cells to serve as back up power for mission critical loads – ILS and other communication systems.

2.0 Name, Address and Related Company Information

ReliOn, Inc.	DUNS #: 137264193
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Spokane, WA 99216	TIN: 912191190
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ReliOn, Inc., a privately held, small business, headquartered in Spokane, Washington, manufactures and markets proton exchange membrane (PEM) fuel cell products based on a unique and patented modular design. The company's current focus is on the sale and installation of highly reliable backup power solutions for critical applications within the telecom, utility and government/military markets.

ReliOn's offering helps customers increase network reliability while reducing overall equipment life-cycle costs in stationary, low power applications, typically requiring 200 watts to 5 kilowatts. Our air-cooled, self-hydrating fuel cells are highly reliable because we require only a minimal balance of plant and are able to bypass potential failure points.

ReliOn, formerly Avista Labs, has been developing, demonstrating and marketing PEM fuel cell technology for the past ten years.

3.0 Production Capability of the Manufacturer

ReliOn, Inc., as described above, will be the manufacturer and integrator of the primary products that comprise the backup power solution. These products are the I-1000's, 1kW fuel cell systems, and the Outdoor Enclosure System which is designed to house the fuel cells, hydrogen fuel and fuel delivery system. ReliOn will oversee the complete installation and commissioning of the backup power solution as well as address all maintenance requirements via company applications engineers.

I-1000 Fuel Cell models and Outdoor Enclosure Systems are available today. ReliOn's current contract manufacturer, Celestica, operates out of its facility in Fort Collins, Colorado and currently has the capability to produce 10 fuel cell systems per week, running one shift only. This capacity can easily be expanded as necessary with the addition of back shifts. ReliOn's plan is to produce 500 I-1000 fuel cells and 250 Outdoor Enclosures in 2005. These outputs are expected to double in 2006.

ReliOn's fuel cells are made from common materials using mature manufacturing processes in injection molded plastic, sheet metal fabrication and printed circuit board

assembly. The membrane electrode assemblies (MEA) are purchased through a supply agreement with 3M.

4.0 Principal Investigator(s)

Mr. Gerry Snow
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5.0 Authorized Negotiator(s)

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Mr. Jon Frost
Vice President, Global Sales
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509-228-6506
jfrost@relion-inc.com

6.0 Past Relevant Performance Information

ReliOn currently has more than 110 fuel cell systems installed and operational in commercial applications covering 4 continents. Our fuel cell systems and backup power solutions have achieved numerous safety and performance certifications including; CSA, CE and NEBS Level III (telecom).

ReliOn's experience is inclusive of the following installations:

- **The Federal Aviation Administration;**
  - Palwaukee, IL, Radio Transmitter Receiver, December, 2003
  - Swinns Valley, WI, Microwave, June, 2004
  - Wakeman, OH, Microwave, August, 2004
  - Fargo, ND, RCAG, September, 2004
  - Average turn-key cost was approximately $35,000

- Contacts: Mr. Stanley Lee, General Engineer, 847-294-8457;
  stanley.lee@faa.gov
  Mr. Steve Aldridge, Environmental Engineer, 952-997-9264;
  steve.aldridge@faa.gov

- **The Bureau of Reclamation;**
  - Loveland, CO, Microwave, October, 2003
  - System cost was approximately $15,000
  - Contact: Mr. Nathan Myers, Electrical Engineer, 303-445-2633
    nmyers@do.usbr.gov

- **The States of Maryland and Ohio;**
  - 2 Sites in MD, 4 Sites in OH
  - E-911 radio equipment, August 2003 to October, 2004
  - Average turn-key cost was approximately $30,000 (no outdoor enclosure)
  - Contact: Mr. George Milne, COO, havePOWER, 202-299-0506
    gmilne@havepower.com

7.0 Host Facility Information

Fort Lewis, part of Forces Command, is the home of I Corps. I Corps was initially activated at Neufchateau, France on January 15 1918, and has participated in more campaigns than any other corps. I Corps is the most decorated corps in the active Army and is the only corps ever to receive the U.S. Presidential Unit Citation. The Corps' primary focus is Pacific Rim. As a result, I Corps has a close, ongoing relationship with Pacific Command. A noteworthy monument to the U.S. Army 4th Infantry Division, stationed at Ft. Lewis between 1956 and 1966, is just inside the main gate and is shown in Figure 1.

The project at Ft. Lewis Army Base is located around Gray Army Airfield and consists of four individual installation sites – Localizer, Glide Slope, Middle Marker beacon and Outer Marker beacon. The Localizer and Glide Slope are located on Gray Army Airfield, within the property of Ft. Lewis. The Middle Marker is located outside of Gray Army Airfield but still within Ft. Lewis and the Outer Marker is gated in an area located approximately 1 mile north of Ft. Lewis on a property known as Goddard Woods. Each site utilizes one ReliOn I-1000 (1kW) fuel cell system as a source of backup power for instrument landing system (ILS) equipment. The installation site locations are shown in Figure 2. Photographs of each site are shown in Figure 3.

Figure 1. Statue at Ft. Lewis Honoring the 4th Infantry Division "To The Steadfast And Loyal Infantrymen Of The Famous Fourth"

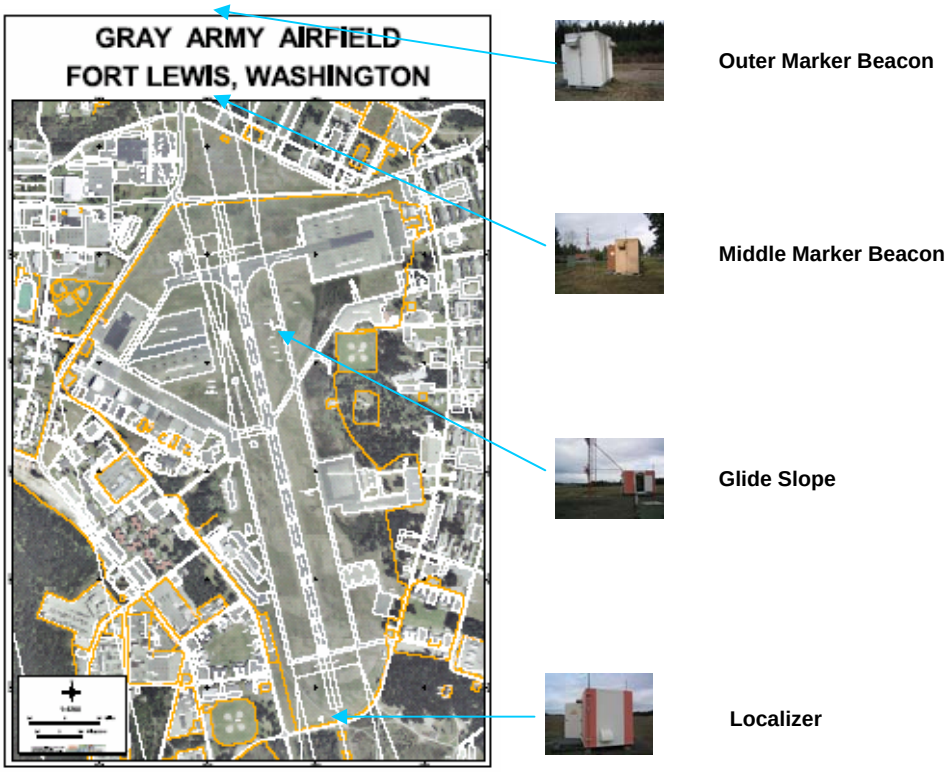

Figure 2. Gray Army Air Field Instrument Landing System Locations

Localizer

Glide Slope

Middle Marker Beacon

Outer Marker Beacon

Figure 3. Gray Army Airfield Instrument Landing System Shelters

8.0 Fuel Cell Installation

The ReliOn Fuel Cell Outdoor Enclosure is a self-contained, turn-key system that is delivered to the site ready to set on the concrete pad and wire in to AC and DC circuits and connect to a local analogue telephone line. The Scope of Work supplied by ReliOn to the general contractor for installation of the fuel cell systems at Ft. Lewis including all power wiring and signal and control interconnection is given in Appendix 1. Installation drawings for the four fuel cell installation sites at Ft. Lewis are included in Appendix 2.

Site work for the four installations at Ft. Lewis began during the third week of May 2004. All equipment was installed by June 15 allowing ReliOn engineers to complete final signal and control connections and initiate system commissioning. All fuel systems were started and tested between June 29 and July 1. The Localizer, Glide Slope, and Middle Marker sites were fully commissioned on July 16 and the 1-year test program was started on that date. Installed ReliOn fuel cell systems at the Localizer, Glide Slope, and Middle Marker are shown in Figure 4. Poor data communication with the Outer Marker site delayed the start of the 1-year test program until the local telephone service provider was able to troubleshoot and repair the line. The 1-year test program at the Outer Marker was started on August 17, 2004.

Localizer

Glide Slope

Middle Marker Beacon

Figure 4. ReliOn Fuel Cell Installations at Localizer, Glide Slope, and Middle Marker

The daily test runs are scheduled to occur during normal business hours over periods of representative equipment loads. This also allows ease of scheduling if host site personnel, ReliOn staff, and guests wish to observe the tests. The data from the laptop computer in each enclosure is downloaded to a server at ReliOn by remote dial-up after each system test run. The data logging computer also has an alarm notification utility that automatically dials preprogrammed phone numbers to notify ReliOn personnel of any alarm condition. One analogue POTS telephone line is used for remote monitoring at each site. The tests at Ft. Lewis are timed as shown in Table 1.

Table 1. Ft. Lewis CERL Test Schedule

Site No.	Site Name	Local Test Time (Pacific)
3-1	Ft. Lewis Localizer	9:00 AM
3-2	Ft. Lewis Glide Slope	10:30 AM
3-3	Ft. Lewis Middle Marker	12:00 PM
3-4	Ft. Lewis Outer Marker	1:30 PM

The test run simulates a power outage everyday for a 60-minute time period in order to test the availability of the fuel cell system. A programmable logic controller (PLC) is installed with each system to simulate the grid outage by opening a relay to cut AC power to the ILS equipment. The PLC also monitors the run status of the fuel cells and will reconnect AC power to the ILS equipment should there be any type of operational failure that could jeopardize the protected equipment. The fuel cells are connected directly to the 24 Volt DC bus at each site. Once a day, AC power to the ILS equipment is disconnected. At the same time, the fuel cells start and provide power to the loads for 1 hour. At the end of the test period, AC power is restored and the fuel cells shut down.

In addition to the daily test, the fuel cell systems are configured to monitor the commercial AC power grid as well as the status of the existing DC backup batteries at each site. Upon loss or failure of either power source, the fuel cells will start automatically to provide up to 48 kWh of continuous run power to critical equipment at each site.

On-site maintenance is required when an alarm condition can not be corrected remotely. Routine inspections and maintenance visits are normally scheduled once per quarter. The ReliOn Independence series is a system based on removable cartridges that house the PEM membranes. If a membrane fails, the system continues to operate and there is a visual indication, as well as remote indication capability with the communications system. When it is convenient, the failed cartridge can be replaced. This task can be accomplished in less than one minute without the use of tools.

9.0 Electrical System

At each of the four sites, the fuel cell systems run in a grid-independent mode with the only interconnection being an AC sensing circuit in the fuel cell enclosure. A block diagram showing relationship between the fuel cell system and existing ILS equipment is shown in Figure 5.

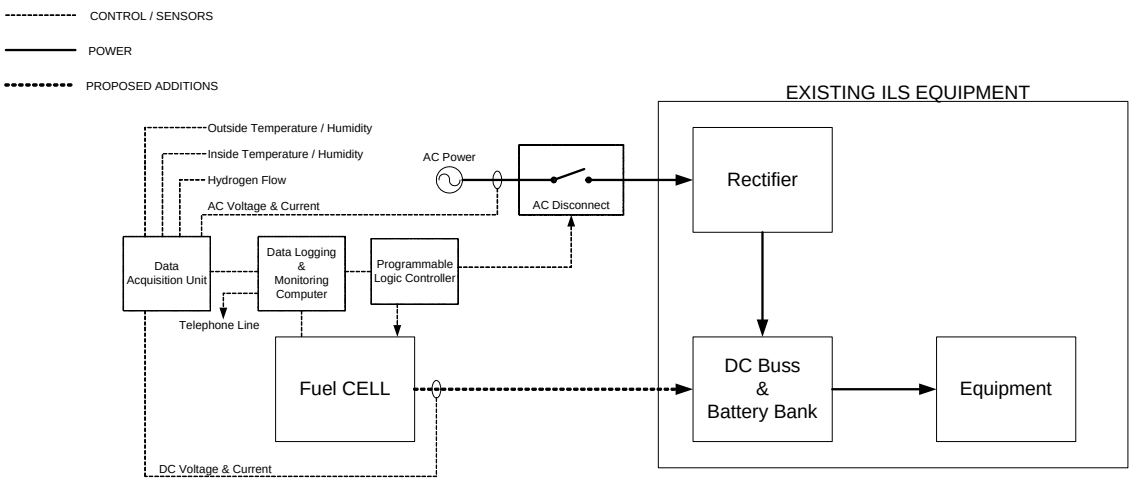

Figure 5. Functional Block Diagram Showing Fuel Cell System Interconnection with Existing Equipment

All systems are in a standby/ready mode to provide backup power for critical DC equipment when there is a loss of primary AC power. The following connections have been established at each site:

- Electrical Requirements:
  - One 20 Amp circuit at each site for AC sense and the enclosure heater. The heater is designed to keep the environment around the fuel cell above freezing to facilitate startup. Once the fuel is running, it utilizes its own heat for operation.
  - AC disconnect relay between AC power and rectifier
  - DC connection between fuel cell system and DC bus in customer's equipment cabinet
  - The PLC, data monitoring equipment, and data logging computer are powered from the 24 VDC terminals inside the enclosure. This ensures that the data continue to be recorded during an extended AC outage.
- Telephone Lines
  - One phone line required per site for data monitoring
  - One computer with dial-up capability at each site
  - See Appendix 2 for site specific connections

10.0 Thermal Recovery System

Because ReliOn's PEM fuel cells operate at low temperatures, the system is not a cogeneration system. The system will be installed in an outdoor enclosure designed to maintain the internal temperature within the operating range of the I-1000.

11.0 Data Acquisition System

The load at each ILS shelter is between 50 watts and 200 watts. A Programmable Logic Controller (PLC) is used to start the fuel cell once a day for a test period of one hour. The PLC also energizes a relay at the same time to disconnect AC power from the shelter rectifier.

A data acquisition system is also included in each enclosure to monitor and record the following:

- Inside temperature

- Inside Humidity
- Outside Temperature
- Outside Humidity
- AC Voltage at the site
- AC current at the shelter rectifier
- DC Voltage at the shelter DC bus
- DC current from the fuel cell
- Hydrogen fuel flow

All vital information from the I-1000 fuel cell is also monitored and recorded. The data-logging computer is connected to the data acquisition module and fuel cell via Ethernet. The data-logging computer is configured to dial a designated ReliOn personnel cell phone during any of the following alarm conditions:

- Loss of AC Voltage
- Low DC Voltage (Less than 23 VDC)
- Hydrogen Sensor Alarm
- Fuel Cell Major Alarm
- Hydrogen Bank Empty
- Enclosure Fan Alarm

The system is also be configured to start automatically during a loss of the AC grid and in the event the facility DC bus voltage falls below a pre-determined limit (low voltage startup). The low voltage startup protects the ILS equipment in case of a facility rectifier/charger failure or a fault in the battery string. The low voltage start threshold has been set at 23 VDC for the ILS systems at Ft. Lewis.

Daily run data for each site is available at ReliOn's customer data website at http://www.relion-inc.com/customers/cerl3/. Contact ReliOn's CERL Project Principal Investigator for login name and password. Monthly run data summaries through January 2005 are included in Appendix 3.

12.0 Fuel Supply System

The fuel cell systems are fueled with industrial grade hydrogen gas. Compressed gas is the easiest and most commercially available source of industrial grade hydrogen. The outdoor enclosure includes two locked hydrogen storage and delivery systems which ensure that the compressed hydrogen cylinders are protected and accessible only to authorized personnel. A sketch of the hydrogen compartments is shown in Figure 6.

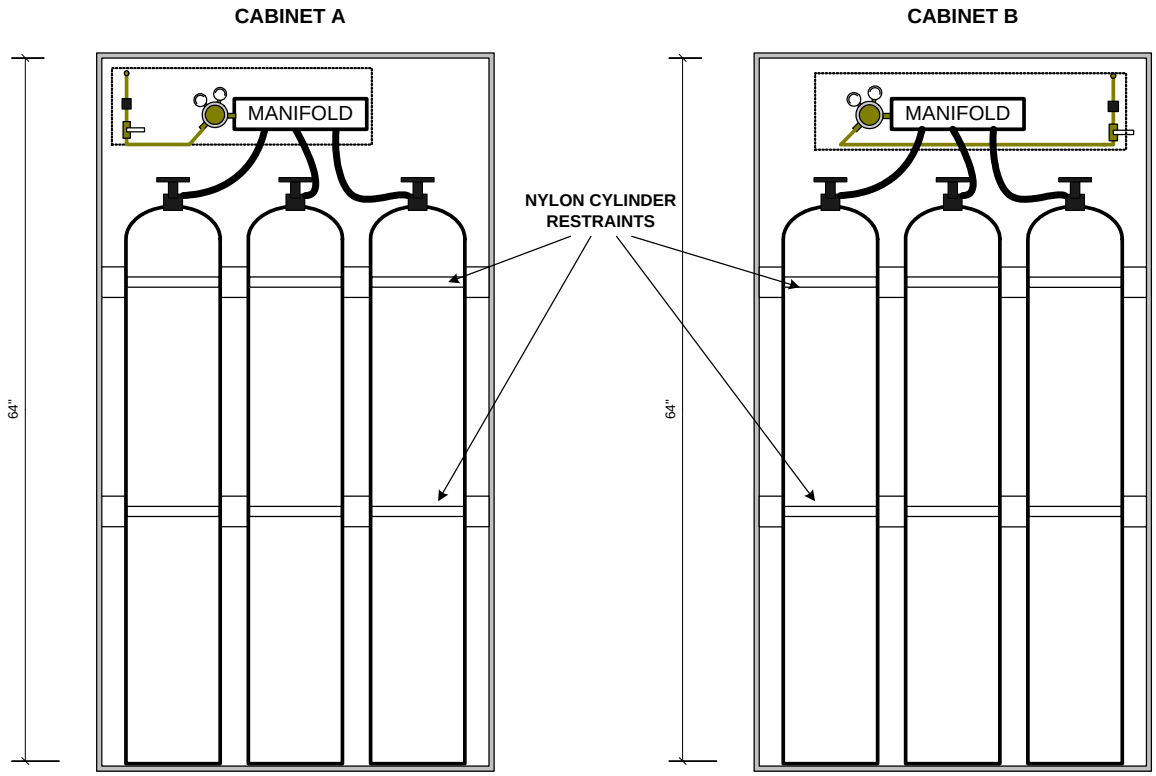

Figure 6. Hydrogen Fuel Compartments

The cylinders are typically size 300 (nominal 285 cu. ft or 8071 liter gas capacity at STP conditions), although size 200 can also be accommodated. Full cylinders are delivered with gas pressure at between 2000 and 2200 psig. Each of two hydrogen storage compartments contains three (3) cylinders directly connected into a high pressure manifold. The manifolds are each equipped with pressure switches and a regulator to reduce the gas pressure for delivery to the fuel cell. The pressure switches are monitored by the data logging computer which will send an alarm to the ReliOn personnel when the gas pressure falls to a pre-determined level. Hydrogen gas deliveries are made to each site by the local distributor for Airgas, Inc. at approximately 6 week intervals. Additional deliveries are made as required in the event of an extended AC grid outage or if extra testing is conducted.

The optimal setting for the pressure regulators to the fuel cell is 40-50 psig. By adjusting the regulated pressures so that one bay is 5-10 psig higher than the other side, hydrogen will flow out of the higher side only until those cylinders are exhausted. The system will then draw hydrogen from the other side allowing time to order and replace the depleted cylinders.

The fuel supply system and refill logistics have worked well so far in the project, apart from a fuel outage in October at the Localizer site. Closer site monitoring and improved fuel delivery scheduling has prevented further fuel outages.

13.0 Installation Costs

Table 2 shows a breakdown of project costs thru January 2005 for the ReliOn PEM fuel cell backup power demonstration project at Ft. Lewis, Washington. The total project proposed cost including ReliOn's profit and cost share for the entire contract was $363,781.64. Of this amount, $135,006 was allocated for the Ft. Lewis site. Total expenditures charged to CERL through January 2005 for Ft. Lewis are $121,549.

Table 2. Project Costs for Contract Number W9132T-04-C-0017 (Ft. Lewis Site)

Task 1: Fuel Cell Power Plant **Direct Labor**		Plan			Actual Through January 2005
Staff	Activity	Units	Unit Cost	Total Cost	
Applications Engineer	Training			$300	$300
Equipment					
I-1000 Fuel Cell		4	$8,050	$32,200	$32,200
Enclosure w/2 Fuel Wings		4	$5,950	$23,800	$23,800
Task 1 Subtotal Budget				**$56,300**	**$56,300**

Task 2: Installation **General/Electrical Contractor**	Plan			Actual Through January 2005
General Contractor			$3,200	$3,200
Electrical Contractor			$6,400	$6,400
Materials & Expenses				
Crane/Fork Lift			$2,000	$2,000
Telecommunications			$20,000	$20,000
Task 2 Subtotal Budget			**$31,600**	**$31,600**

Task 3: Performance Monitoring **Direct Labor**		Plan			Actual Through January 2005
Staff	Activity	Units	Unit Cost	Total Cost	
Applications Engineer	Monitoring & Data Management			$2,600	$504
Principal Investigator	Monitoring & Data Management			$1,200	$1,380
Task 3 Subtotal Budget				**$3,800**	**$1,884**

Task 4: Maintenance **Direct Labor**		Plan			Actual Through January 2005
Staff	Activity	Units	Unit Cost	Total Cost	
Applications Engineer	On Site Training			$300	$300
Applications Engineer	Remote & Site Maintenance			$1,200	$800
Principal Investigator	Remote & Site Maintenance			$0	
Task 4 Subtotal Budget				**$1,500**	**$1,100**

Task 5: Project Management & Reporting **Direct Labor**		Plan			Actual Through January 2005
Staff	Activity	Units	Unit Cost	Total Cost	
Project Manager	Management, Reporting, Meetings			$1,200	$1,575
Principal Investigator	Management, Reporting, Meetings			$800	$700
	Initial Project Description			$600	$600
	Monthly Status Report			$300	$230
	Midpoint Report			$600	$600
	Final Report			$600	$0
Task 5 Subtotal Budget				**$4,100**	**$3,705**

Table 2 (Continued).
Project Costs for Contract Number W9132T-04-C-0017 (Ft. Lewis Site)

Task 6: Travel		Plan			Actual Through January 2005
Managerial Travel				$367	$367
Technical Travel-Installation				$2,591	$5,733
Technical Travel-Maintenance				$2,016	$1,500
Technical Travel-Decommissioning				$1,496	$0
Task 6 Subtotal Budget				**$6,470**	**$7,600**

Task 7: Decommissioning/Site Restoration		Plan			Actual Through January 2005
Direct Labor					
Staff	Activity	Units	Unit Cost	Total Cost	
Applications Engineer	Site Work			$0	$0
Principal Investigator	Site Work			$0	$0
General/Electrical Contractor					
Labor				$6,400	$0
Materials & Expenses					
				$4,000	$0
Task 7 Subtotal Budget				**$10,400**	**$0**

Task 8: Other Costs	Plan			Actual Through January 2005
Equipment & Expenses				
Hydrogen Fuel			$12,200	$9,250
Electrical Equipment			$10,000	$10,000
Task 8 Subtotal Budget			**$22,200**	**$19,250**

Ft. Lewis Total Budget	**$136,370**	**$121,439**
Profit (10%)	$13,637	$12,144
Ft. Lewis Total Project Cost	**$150,007**	**$133,583**
ReliOn Cost Share (10%)	($15,001)	($12,034)
Ft. Lewis Total Project Billing	**$135,006**	**$121,549**

14.0 Acceptance Test

Commissioning procedures involve manual system start-ups and shut-downs, verification of loss of AC auto starts, verification of low battery voltage auto starts, and verification of system alarm functionality. ReliOn commissioning instructions for commercial installations of the I-1000/Outdoor Fuel Cell System are given in Appendix 4. Test and demonstration installations that include PLC controllers, data monitoring and recording equipment, computer logging, and remote data communication are subject to further commissioning procedures to verify functionality, data logging, and communication processes.

The final part of the acceptance test at each site is the measurement of voltage stability while providing power to the equipment under normal load conditions. Results of these tests at Ft. Lewis are shown in Figures 7 through 10. As indicated, the maximum measured voltage variation of each fuel cell system was well less than the product engineering specification of < 1.0 VDC peak to peak at 100 kHz.

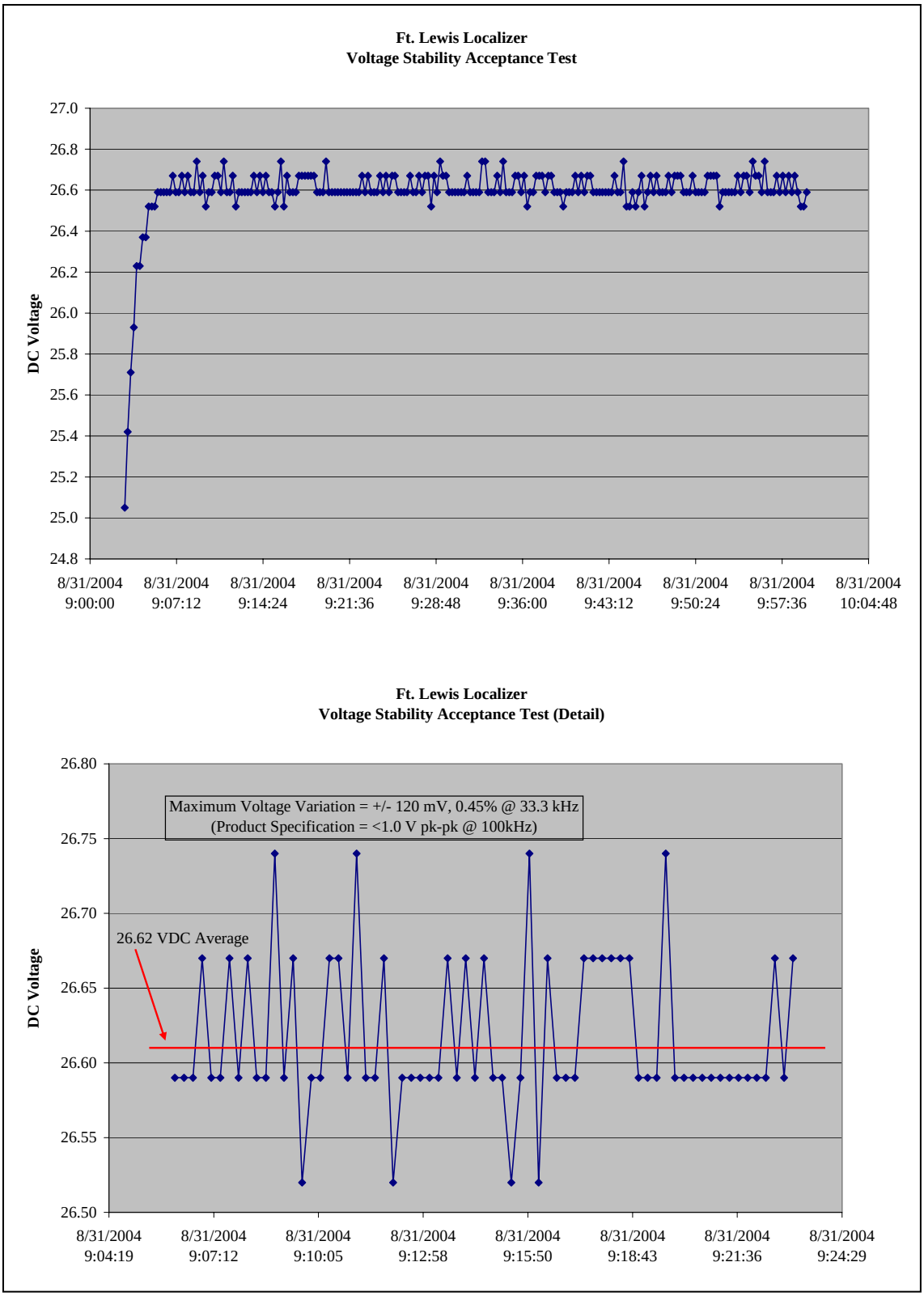

Figure 7. Ft. Lewis Localizer
Fuel Cell Voltage Stability Test

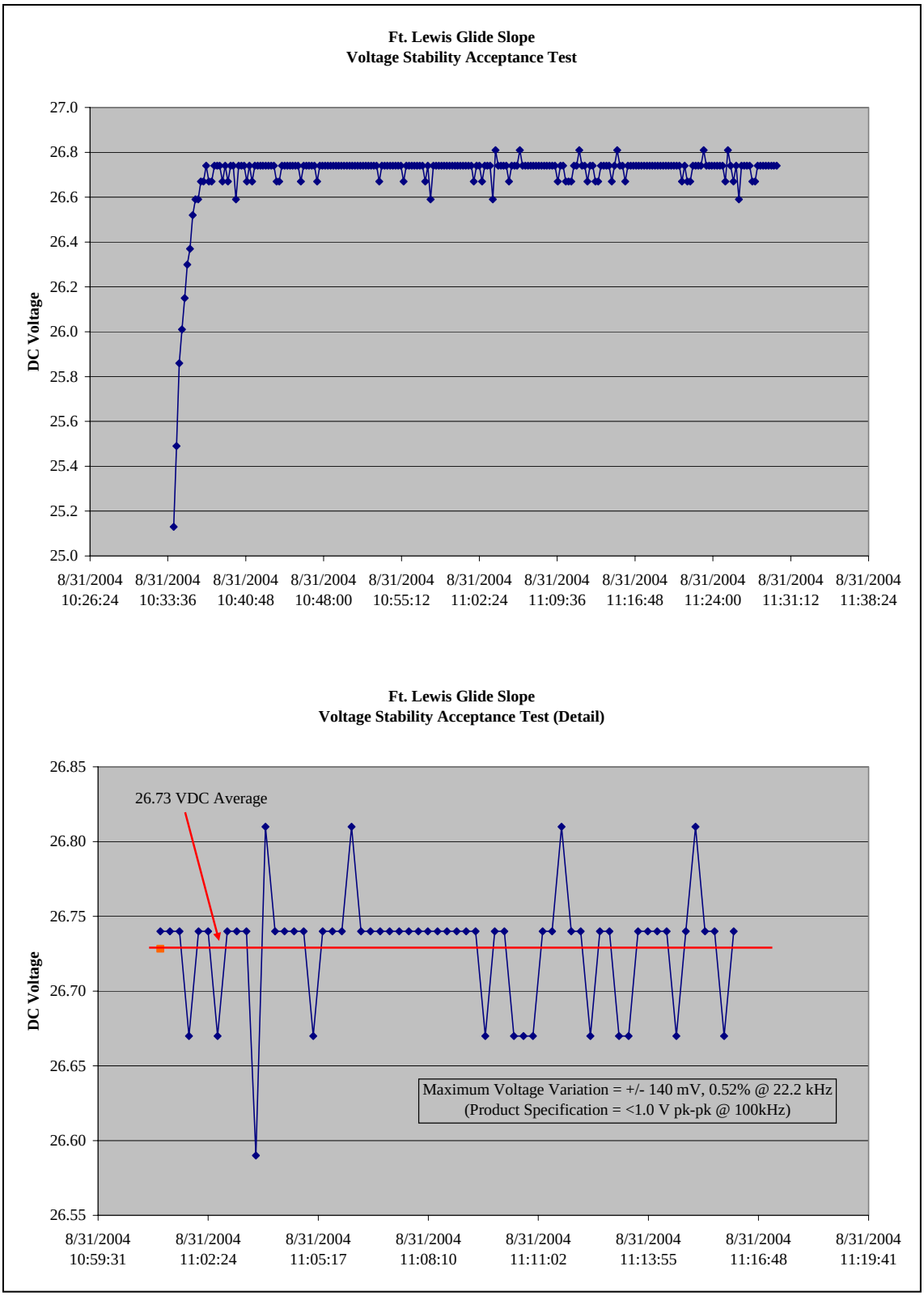

Figure 8. Ft. Lewis Glide Slope
Fuel Cell Voltage Stability Test

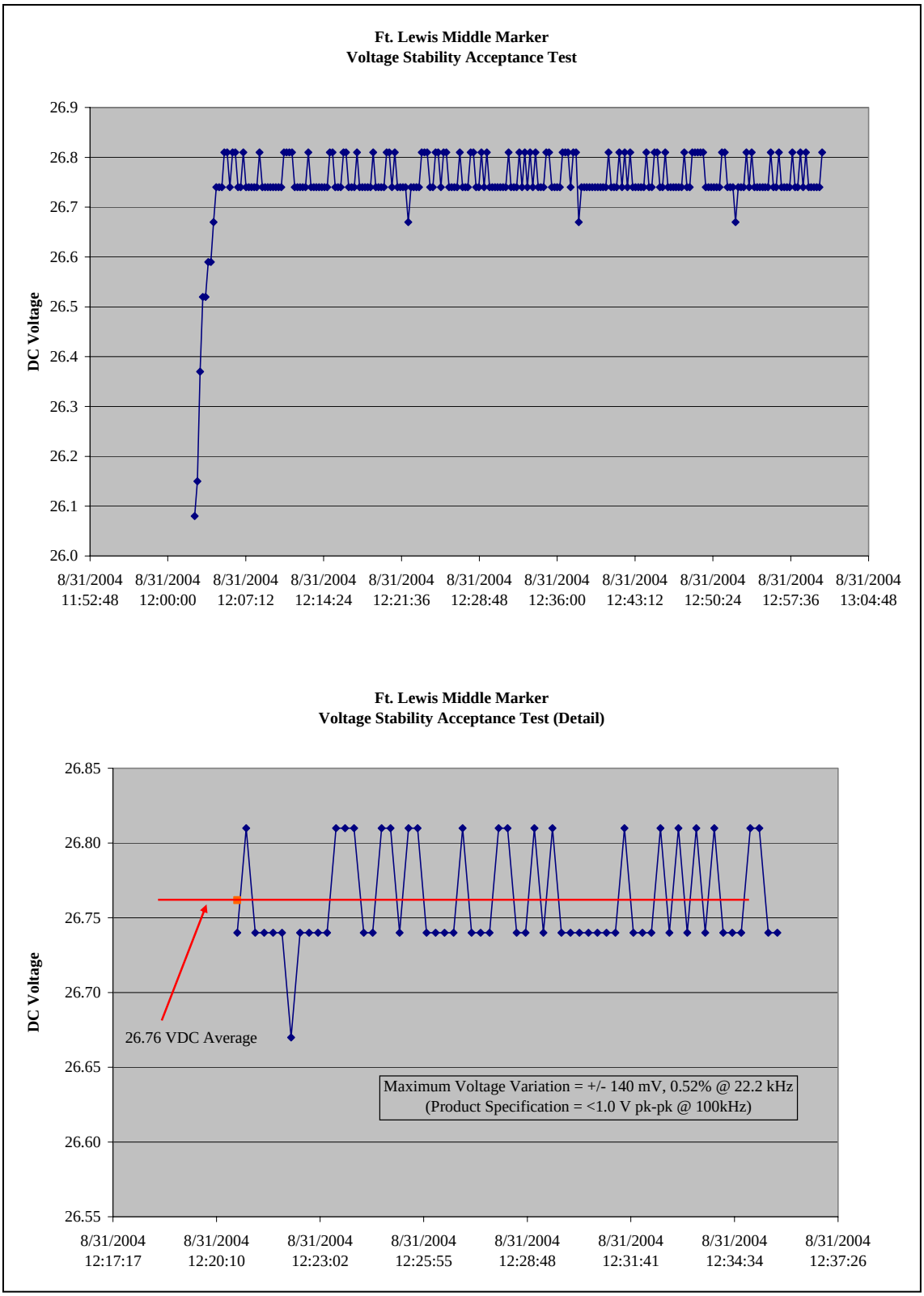

Figure 9. Ft. Lewis Middle Marker
Fuel Cell Voltage Stability Test

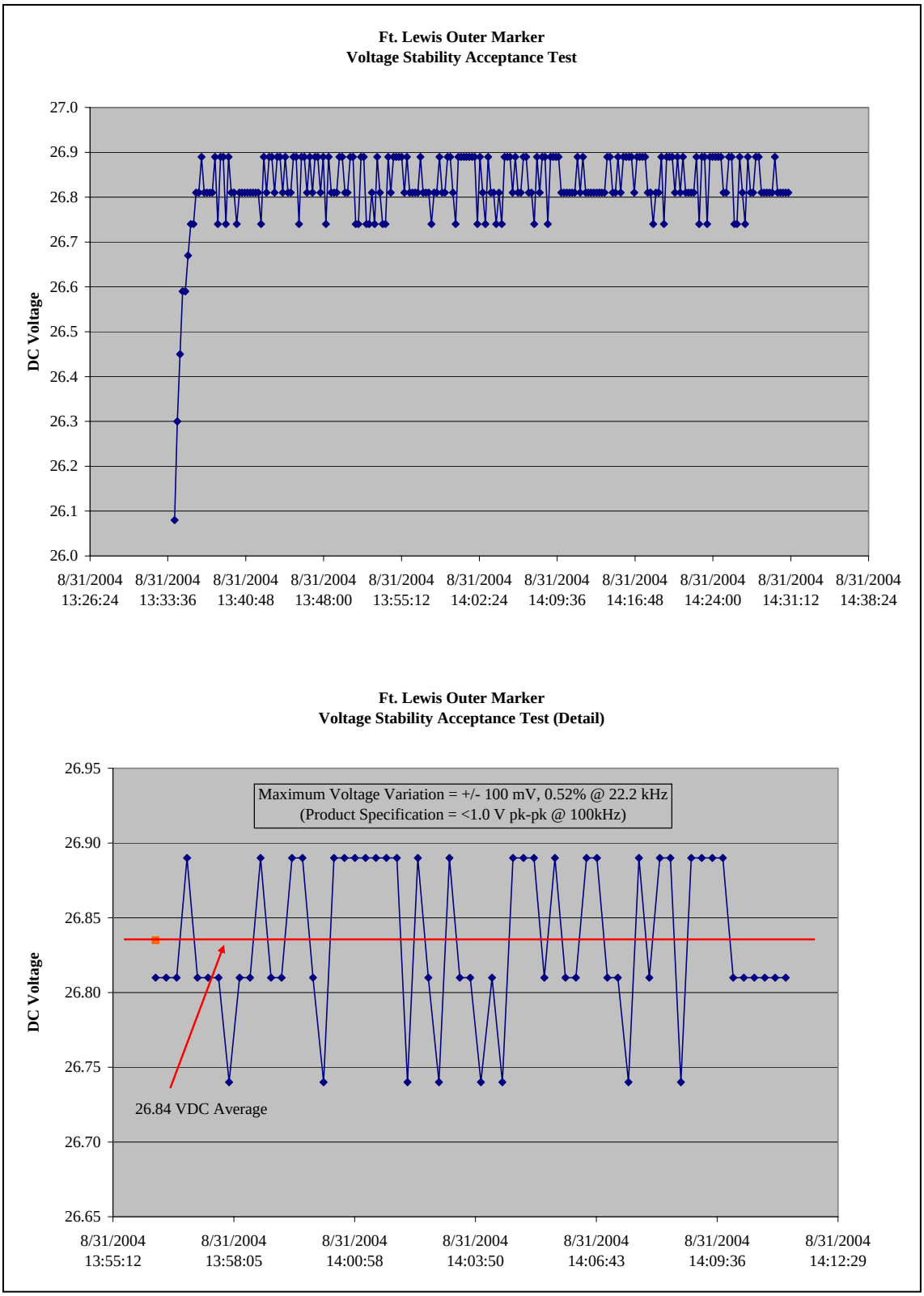

Figure 10. Ft. Lewis Outer Marker
Fuel Cell Voltage Stability Test

Appendix

1) ReliOn Fuel Cell System Site Preparation Contractor Scope of Work
2) Ft. Lewis Fuel Cell Installation Drawings
3) Monthly Performance Data
4) Commissioning Procedures for the I-1000™ Fuel Cell & Outdoor Enclosure System